



Cairo University

# **TECHNICAL AND ECONOMICAL FEASIBILITY OF BENEFICIATING (ABU-TARTUR) PHOSPHATE DEPOSIT**

**By**

**Nabil El-Sayed Abdel Rahman El-Sharkawy**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of

**MASTER OF SCIENCE  
In  
Mining Engineering**

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT**

2017

**TECHNICAL AND ECONOMICAL FEASIBILITY  
OF  
BENEFICIATING (ABU-TARTUR) PHOSPHATE DEPOSIT**

**By  
Nabil El-Sayed Abdel-Rahman El-Sharkawy**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of

**MASTER OF SCIENCE  
In  
Mining Engineering**

Under the Supervision of

**Prof. Dr. Ayman A. El-Midany**

Mining, Petroleum, and Metallurgical  
Department.  
Faculty of Engineering, Cairo University

**Prof. Dr. Hassan El-Sayed El-Shall**

Mining, Petroleum, and Metallurgical  
Department.  
Faculty of Engineering, Cairo University

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT**

2017

**TECHNICAL AND ECONOMICAL FEASIBILITY  
OF  
BENEFICIATING (ABU-TARTUR) PHOSPHATE DEPOSIT**

**By  
Nabil El-Sayed Abdel- Rahman El-Sharkawy**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of

**MASTER OF SCIENCE  
In  
Mining Engineering**

**Approved by the**

**Examining Committee:**

<b>Prof. Dr. Ayman A. El-Midany,</b>	<b>Thesis Main Advisor</b>
<b>Prof. Dr. Hassan El-Sayed El-Shall,</b>	<b>Advisor</b>
<b>Prof. Dr. Ahmed Abdel- Aziz Ahmed,</b>	<b>Internal Examiner</b>
<b>Prof. Dr. El-Sayed Ali Abdel- Aal,</b>	<b>External Examiner</b>

**Central Metallurgical Research Institute**

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT**

**2017**

**Engineer's Name:** Nabil El-Sayed Abdel- Rahman El-Sharkawy  
**Date of Birth:** 10/2/1965  
**Nationality:** Egyptian  
**E-mail:** [Nabil1201200@gmail.com](mailto:Nabil1201200@gmail.com)  
**Phone:** 01006034983  
**Address:** Zawyit-biltan –Toukh –Qalyubia  
**Registration Date:** 1/3/2013  
**Awarding Date:** 2017  
**Degree:** Master of Science  
**Department:** Mining Engineering

Insert photo here

**Supervisors:**

**Prof. Dr. Ayman A. El-Midany.**  
**Prof. Dr. Hassan El-Sayed El-Shall**

**Examiners:**

**Prof. Dr. Ayman A. El-Midany (Thesis main advisor)**  
**Prof. Dr. Hassan El-Sayed El-Shall (Advisor)**  
**Prof. Dr. Ahmed Abdel- Aziz Ahmed (Internal examiner)**  
**Prof. Dr. El-Sayed Ali Abdel- Aal (External examiner )**  
(Central Metallurgical Research Institute)

**Title of Thesis:**

Technical and Economic Feasibility of Beneficiating Abu-Tartur Phosphate Deposit

**Key Words:**

Beneficiating plant; phosphate concentrate; mining engineering; phosphoric acid; magnesium

**Summary:**

Abu-Tartur plateau are exploited by open cast of a layer ranges in thickness between 3.9 to 4.5 meters. The average  $P_2O_5$  content is 24%. The impurities are mostly iron and magnesium carbonates with low silica content. Therefore, the beneficiation step is mandatory to produce a phosphate concentrate for merchant grade phosphoric acid and phosphate fertilizers.

In this study, five flow sheets with different setup and machineries were tested and compared to the current flowsheet at the Misr phosphate company. Each flowsheet was tested technically in terms of grade and recovery of the produced concentrate and economically in terms of the cost of the produced ton of concentrate with the required grade. A concentrate containing 30%  $P_2O_5$  was obtained at a cost ranges from 183 to 212 Egyptian pounds per ton. The main result is the same concentrate can be produced by about 30 pounds less in cost by selection of the proper flowsheet and machinery.

## **Acknowledgments**

First of all, I'm deeply thankful to "Allah" for gifting me, making such a work possible.

I would like to express my deep thanks and appreciation to Prof. Dr- Hassan El-Sayed El-Shall – emeritus professor of mineral processing, Mining Department, Cairo University. For his guidance and supervision in the course of the work, and his stimulating criticism and help in the preparation of the manuscript. For teaching me how to think, study and work things to get solution to any problem in my whole practical life.

Also, I'm very grateful to Prof. Dr. Ayman A. El-Midany – Head of Mining Division and Professor of mining engineering in Cairo University – Mining Department – for suggesting the problem, direct supervision, valuable comments and discussions and kind help during this work.

My thanks and best wishes to all members of - Misr Phosphate Company – (New Valley phosphate project)

## **Dedication**

I dedicate this work to my family and my friends for their love, support and encouragement which gave me the strength to overcome many obstacles.

# Table of Contents

<b>Acknowledgments</b>	<b>I</b>
<b>Dedication</b>	<b>II</b>
<b>Table of Contents</b>	<b>III</b>
<b>List of Tables</b>	<b>VII</b>
<b>List of Figures</b>	<b>VIII</b>
<b>Nomenclature</b>	<b>IX</b>
<b>Abstract</b>	<b>X</b>
<b>Chapter 1 Introduction</b>	<b>1</b>
1.1. Description of the Phosphate Deposit.	2
1.1.1. Phosphate Types and Associated Gangue Minerals.	2
1.1.2. Specification of phosphate ores for phosphoric acid industry.	3
1.1.3. Status of phosphate production in the world and Egypt.	3
1.1.3.1. Phosphate production in the world:	3
1.1.3.2. Phosphate industry in Egypt:	4
1.2. Location	4
1.2.1. Phosphate Deposit in the world	4
1.2.2. Distribution phosphate deposit in Egypt.	5
1.3. General Geology	7
1.3.1. Stratigraphy	7
1.4. Mineral petrographic characteristics of phosphate	9
1.4.1. Primary( non-weathered) phosphate	9
1.4.2. Secondary( weathered) phosphate	9
1.4.3. Enclosing rocks [13, 19, 25]	9
1.5. Resources	11
1.6. Exploration work (research)	11
1.7. Reserves	13
1.8. Historical Development	14
1.8.1. Development	15
1.8.1.1. Long well development	15
1.8.1.2. Open cast development	15

<b>1.8.1.3. Mining</b>	<b>16</b>
<b>Chapter 2 : Technical and Economic Feasibility of Beneficiation of Abu-Tartur Phosphate Deposit</b>	<b>18</b>
2.1. Crushing	18
2.2. Ore dressing	18
2.2.1. Types of Abu-Tartur deposit [5]	18
2.2.1.1. Primary (non-weathered) phosphate	18
2.2.1.2. Secondary (weathered) phosphate	18
2.2.2. Basic principles of beneficiation:	21
2.2.3. Principles of beneficiation:	23
2.2.3.1. The mineralogical composition	24
2.2.3.2. Technological sampling for beneficiation test:	25
2.2.4. Beneficiation technology of Abu-Tartur phosphates	26
2.2.4.1. Mineral impurity:	26
2.2.4.2. Methods used for removing dolomite:	27
2.2.4.3. Concentrate Drying:	29
2.2.4.4. Characteristics of feed ore:	29
2.2.4.5. The advantages of Abu-Tartur phosphate rock are:	29
2.2.5. Description of the of beneficiation process	30
2.2.5.1. Equipment of beneficiation plant	30
2.2.5.2. Description of the concentrate production:	32
<b>Chapter 3 : Main equipment of beneficiation plant and cost</b>	<b>34</b>
3.1.1. The foundation on which equipment were selected equipment and basis of choosing the right design:	35
3.1.2. The foundation on which it was deprecation expensive	35
3.1.3. Equations used to calculate the total cost To produce 1 ton ore concentrate for:	36
3.2. Calculation of the total cost to produce 1 ton concentrate	37
3.2.1. Main Design table 3.2	37
3.2.1.1. Calculate the cost of production of 1 ton concentrate	39
3.2.1.2. Characteristics of The Main Design	41
3.2.1.3. Equipment used:	41



3.2.1.4.	<i>The basic Criteria for equipment selection</i>	41
3.2.1.5.	<i>Characteristics of R.O.M Ore.</i>	41
3.2.1.6.	<i>Characteristics of Ore Product:</i>	41
3.2.1.7.	<i>Economical side:</i>	41
3.2.2.	<i>Design No. (1)-Table 3.3</i>	42
3.2.2.1.	<i>Calculation of production cost of 1 ton concentrate from design(1)</i>	44
3.2.2.2.	<i>Characteristics of Design No. (1)</i>	46
3.2.2.3.	<i>Equipment used:</i>	46
3.2.2.4.	<i>The basic Criteria for equipment selection</i>	46
3.2.2.5.	<i>Characteristics of R.O.M Ore.</i>	46
3.2.2.6.	<i>Characteristics of Ore Product:</i>	46
3.2.2.7.	<i>Economical side:</i>	46
3.2.3.	<i>Design No. (2)-Table 3.4</i>	47
3.2.3.1.	<i>Calculation of the cost of production of 1.0 ton concentrate using design(2)</i>	49
3.2.3.2.	<i>Characteristics of Design No. (2)</i>	51
3.2.3.3.	<i>Equipment used:</i>	51
3.2.3.4.	<i>The basic Criteria for equipment selection</i>	51
3.2.3.5.	<i>Characteristics of R.O.M Ore.</i>	51
3.2.3.6.	<i>Characteristics of Ore Product:</i>	51
3.2.3.7.	<i>Economical Side</i>	51
3.2.4.	<i>Design No. (3)-Table 3.5</i>	52
3.2.4.1.	<i>Calculation of the cost of production of 1.0 ton concentrate using design(3)</i>	54
3.2.4.2.	<i>Characteristics Design No. (3)</i>	56
3.2.4.3.	<i>Equipment used:</i>	56
3.2.4.4.	<i>The basic Criteria for equipment selection</i>	56
3.2.4.5.	<i>Characteristics of R.O.M Ore.</i>	56
3.2.4.6.	<i>Characteristics of Ore Product:</i>	56
3.2.4.7.	<i>Economical Side</i>	56
3.2.5.	<i>Design No. (4)-Table 3.6</i>	57

3.2.5.1.	Calculation of the cost of production of 1.0 ton concentrate using design(4)	59
3.2.5.2.	Characteristics Design No. (4)	61
3.2.5.3.	Equipment used:	61
3.2.5.4.	The basic Criteria for equipment selection	61
3.2.5.5.	Characteristics of R.O.M Ore.	61
3.2.5.6.	Characteristics of Ore Product:	61
3.2.5.7.	Economical Side	61
3.2.6.	Design No. (5)-Table 3.7	62
3.2.6.1.	Calculation of the production cost of 1.0 ton concentrate using design(5)	64
3.2.6.2.	Characteristics Design No. (5)	66
3.2.6.3.	Equipment used:	66
3.2.6.4.	The basic Criteria for equipment selection	66
3.2.6.5.	Characteristics of R.O.M Ore.	66
3.2.6.6.	Characteristics of Ore Product:	66
3.2.6.7.	Economical Side	66
Chapter 4 : Conclusions		75
Chapter 5 : References		78
f		الملخص بالعربية

## List of Tables

Table 1.1 Mineable ore composition Ratio .....	12
Table 2.1 Chemical composition of Abu-Tartur primary Non-weathered phosphate.....	20
Table 2.2 mineral composition of Abu-Tartur primary non-weathered phosphate.....	20
Table 2.3 Chemical composition of Abu-Tartur secondary weathered phosphate .....	20
Table 2.4 Mineral composition of Abu-Tartur secondary weathered phosphate.....	20
Table 2.5 average chemical analysis of Abu-Tartur phosphate sample.....	24
Table 2.6 Average screen analysis for ore feeding .....	24
Table 3.1 Main equipment of beneficiation plant and cost .....	34
Table 3.2 Main Design production cost according to 1 ton concentrate.....	39
Table 3.3 Design 1 production cost according to 1 ton concentrate .....	44
Table 3.4 Design 2 production cost according to 1 ton concentrate .....	49
Table 3.5 Design 3 production cost according to 1 ton concentrate .....	54
Table 3.6 Design 4 production cost according to 1 ton concentrate .....	59
Table 3.7 Design 5 production cost according to 1 ton concentrate .....	64
Table 3.8 Water Cost.....	67
Table 3.9 Electricity Cost.....	67
Table 3.10 Fuel Cost .....	67
Table 3.11 Calcium Carbonate Cost .....	68
Table 3.12 Chemicals cost .....	68
Table 3.13 Fabric Filter Expense .....	68
Table 3.14 The Sum of Cost per design in total.....	69
Table 3.15 Total Cost for every design. ....	70
Table 3.16 Economic analysis of flow-sheets.....	71
Table 3.17 Chemical analysis of The product.....	72

## List of Figures

Figure 1.1 Phosphate World production .....	3
Figure 1.2 Phosphate Spots On Egypt.....	4
Figure 1.3 Egypt Phosphate production World-Rank. ....	4
Figure 1.4 Largest P <sub>2</sub> O <sub>5</sub> Reserves in Egypt .....	5
Figure 1.5 Abu-Tartur phosphate Plateau .....	6
Figure 1.6 Sectors of Phosphate.....	8
Figure 1.7 Exploration boreholes .....	12
Figure 1.8 Maghrabi-Liffia sector .....	14
Figure 1.9 Abu-Tartur Phosphate production over years .....	17
Figure 2.1 Oxidation of the Ore in Relation to Distance from the outcrop .....	25
Figure 2.2 Drum Scrubber (0-3.6m, l = 10m) .....	30
Figure 2.3 2mm screen for wet ore .....	30
Figure 2.4 Hydro cyclones with dolomite ranging from 716mm up to 1000 mm .....	31
Figure 2.5 Attrition machine .....	31
figure 2.6 Hydro-classifiers with diameter of 900 mm .....	31
Figure 2.7 Magnetic separators .....	32
Figure 2.8 Vacuum belt filters with 10.5 m <sup>2</sup> (filtering surface).....	32
Figure 3.1 Flow-Sheet Underground Mining (Non-Weathered Phosphate) .....	40
Figure 3.2 Flow-Sheet of beneficiation of phosphate rock produced by Underground Mining (Non-Weathered Phosphate) .....	45
Figure 3.3 Flow-Sheet for beneficiation of phosphate rock produced by Open Cast Mining (Weathered Phosphate).....	50
Figure 3.4 Flow-Sheet Open Cast Mining (Weathered Phosphate).....	55
Figure 3.5 Flow-Sheet Open Cast Mining (Weathered Phosphate).....	60
Figure 3.6 Flow-sheet for benefciation of phosphate rock produced by Open Cast Mining using desg(5) (Weathered Phosphate).....	65
Figure 3.7 Simplified Beneficiation Block Flow-Sheet (without magnetic separation and attrition cell) .....	73
Figure 3.8 Simplified beneficiation Block Flow-sheet (all equipment).....	74

# Nomenclature

**Montmorillonite:**

Is an aluminum-rich clay mineral of the smectite group, containing some sodium and magnesium.

**Sulphides:**

Is a binary compound of sulfur with another element or group.

**Shale:**

Is a soft, finely stratified sedimentary rock that formed from consolidated mud or clay and can be split easily into fragile slabs.

**Ankerite :**

Primarily is a kind of iron not limited to also with combinations of calcium, magnesium, manganese carbonate mineral of the group of Rhombohedral with the formula  $\text{Ca(Fe,Mg,Mn)(CO}_3)_2$ .

**Gangue:**

Is a worthless material surrounding, covering or mixed with ore - the wanted material - in our case in phosphate deposit and mining.

## Abstract

Abu-Tartur plateau lies 50 km west of El-Kharga city. Currently, Misr phosphate company mining activities are using open cast of a layer ranges in thickness between 3.9 to 4.5 meters. The average  $P_2O_5$  content is 24%. The impurities are mostly iron, magnesium carbonates and silica. It is clear that the beneficiation is a mandatory step to reach the concentrate with phosphoric acid grade.

Beneficiation studies have been conducted to test several beneficiation flow sheets for producing phosphate concentrate for merchant grade phosphoric acid. No doubt that, for industrial plant, during its lifetime, it witnessed various additions and removal of some units, which produced several set-up or flow-sheets. In this research work, five flow sheets were chosen for detailed investigation. The overall goals of This study is to evaluate and compare the Techno-Economic Feasibility of These different Design in order to determine to optimum Beneficiation Flow-Sheet technically in terms of grade and recovery and economically in terms of the cost of the produced ton with the required grade in terms of  $P_2O_5$ . The studied flowsheets for annual production 600000 tons are:

**Main flowsheet:** include all equipment in ore dressing plant for reaching high production where using non-weather ore. Size of feed -6 cm, size of production between -2mm to -0.08mm, yield was about 58% and recovery was about 72%. The produced concentrate contains  $P_2O_5$  31% with ton of concentrate cost 212 LE

**Flowsheet 1:** Similar to the main flowsheet except the withdrawal of magnetic separation unit. Using Size of feed -3 cm, the yield was about 68.5% and  $P_2O_5$  recovery was about 83%. The produced concentrate contains  $P_2O_5$  30% with ton of concentrate cost 190 LE.

**Flowsheet 2:** Similar to the flowsheet 1 except additional of magnetic separation unit. Using weathered ore, Size of feed -6cm, the yield was about 62% and  $P_2O_5$  recovery was about 78%. The produced concentrate contains 31.5%  $P_2O_5$  with ton of concentrate cost 209 LE.

**Flowsheet 3:** Similar to the flowsheet 2 except the withdrawal of magnetic separation and cell attrition, the yield was about 66% and  $P_2O_5$  recovery was about 83%. The produced concentrate contains 31.5%  $P_2O_5$  with ton of concentrate cost  $P_2O_5$  188 LE.

**Flowsheet 4:** Similar to the flowsheet 3, Size of feed -3cm, yield about 68.9% and  $P_2O_5$  recovery about 87%. The produced concentrate contains 31.1%  $P_2O_5$  with ton of concentrate cost  $P_2O_5$  188 LE.

**Flowsheet 5:** Similar to the flowsheet 4, Size of feed -1cm, yield about 76% and  $P_2O_5$  recovery about 91% the produced concentrate contains 30%  $P_2O_5$  with ton of concentrate cost  $P_2O_5$  182 LE.

As a summary of this study, concentrate containing 30%  $P_2O_5$  was obtained at a cost ranges from 182 to 212 Egyptian pounds per ton. The main result is the same concentrate can be produced by about 30 pounds less in cost by selection of the proper flowsheet and machinery.

# Chapter 1

## Introduction

Phosphates, in the form of fertilizers are essential in the agricultural sector. They are also very important constituents in animal feed stocks and in food and other chemical industries. About 95% of the world phosphate rock production is consumed in fertilizer industry.

Economic recovery of phosphates is limited to naturally concentrated phosphate mineral deposits, [1].

Occasionally natural concentrations are enough to be used as mined. Generally if the ore is of low grade it must be concentrated for economic utilization thus beneficiation so techniques are used for concentrating the ore of mine phosphates.

More than 40 countries around the world produce phosphate rock. In 2015 [1] the world phosphate production reached 196 MT out of which 180 MT were produced by sixteen major phosphate producing countries. These countries arranged in descending order of their production capacities are: USA, Morocco, China, Russia, Tunisia, Jordan, Brazil, Syria, South Africa, Egypt, Australia, Senegal, India, Togo and Canada [1].

Only 16 MT are produced by all other countries.

In Egypt phosphate ores are mined from Abu-Tartur plateau Western Desert. The phosphate seam is spread all over the plateau covering an area of about 1200 Km<sup>2</sup>. Only one tenth of that area had been geologically explored by means of 375 surface drill holes. Indicating the presence of about 715 MT of phosphate reserves [2, 3]. The average seam thickness is about 3.3m.

The present exploitation is restricted to an area 14km<sup>2</sup> with reserves about 120 MT can be extracted by open cast methods. The ore currently exploited as a run of mine phosphate (R-O-M) contain an average of 25% P<sub>2</sub>O<sub>5</sub> average is conveyed to a beneficiation plant to be concentrated to 31% P<sub>2</sub>O<sub>5</sub> concentrate. The project is carrying out lots of modifications to rectify and improve the situation especially in beneficiation plant. Then the whole concentrate quantity should be manufactured to fertilizers when the Abu-Tartur chemical fertilizer becomes a reality. Especially the project is well served by a complete network of infrastructure including railway-ways, power supply, water supply, roads and housing [4, 5].